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RECOVERY OF VERMICULITE FROM A PHOSPHATE-ASSOCIATED, CARGILL TWP, ONTARIO, DEPOSIT

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RECOVERY OF VERMICULITE FROM A PHOSPHATE-ASSOCIATED, CARGILL TWP, ONTARIO, DEPOSIT

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SUMMARY

This report details two separate investigations of phosphate-associated vermiculite from Cargill Township, Ontario, that were undertaken under START for Sherritt Gordon Mines.

The first, a preliminary study of surface grab samples, was completed in mid-1983. The study included sample preparation methods and vermiculite/grit separation by sizing and by air jig and table. Results showed differential crushing and sizing to be especially applicable for separating vermiculite/grit in the coarser sizes, and air tabling, in particular, for the finer.

The second study, an extension of the first, made on a much larger, trench sample, was completed in the last quarter of 1984. This more detailed study investigated impact crushing (reduction) of the coarse, plus 12 mm size. The bulk of the vermiculite, following crushing and sizing, reported in the plus 1.5 mm fraction, the grit being essentially minus 1.5 mm in size. Product recovery was in the order of 75 to 80% and grade 92 to 93% vermiculite.

Product recoveries for the minus 12 mm fraction, treated by air jig and table, were, respectively, 33% grading 58% vermiculite, and 24% grading 76% vermiculite.

Thus this sample contained about 45% vermiculite, 87% of which was recovered by a combination of impact crushing and sizing, and air jig and table concentration.

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INTRODUCTION

A cost-recovery study of four grab samples of phosphate-associated vermiculite from Cargill Township, Ontario, was undertaken for Sherritt Gordon Mines in 1982. The results, reported in MRP/MSL 82-6 (1), showed one sample to be of potential interest for the recovery of vermiculite of a size and quantity suitable for the production of loose insulation, and concrete and plaster aggregate.

Further beneficiation studies, under START, were requested in mid-1983 on larger samples. Additional studies, also under START, were made on a much larger trench sample in November/December, 1984. The results of these latter two studies are detailed below under 'Preliminary Investigation' and 'Extended Study'.

PRELIMINARY INVESTIGATION

Sample

The sample lot, as received, weighed about 30 kg and consisted of three separate bags of surface, grab samples. On the advice of D. MacKinnon of Sherritt Gordon, these were combined to make one large sample. The size and composition of the sample material ranged from 'books' of vermiculite up to 100 mm across by 6 to 12 mm thick, and rock 'chunks' measuring 50 to 75 mm across, down to very finely divided particles of both vermiculite and rock (grit). The coarser sizes of vermiculite and rock (above, say 25 mm) represented perhaps 25 to 30% of the total sample.

Processing

The sample was split into two equal portions, one being set aside for reference and future processing, if required. The other was screened at 12 mm and the plus 12 mm stage crushed to minus 12 mm by jaw crusher. The larger 'books' of vermiculite was reduced very little by jaw crusher, initially, and continued to report and to be concentrated in the plus 12 mm fraction from the jaw. This plus 12 mm vermiculite-rich portion from the jaw was then further reduced, to 12 mm by a more vigorous jaw-crushing

action. This, unfortunately, resulted in a marked delamination and reduction of the thickness of the vermiculite 'books' with the accompanying production of excessive quantities of thin sheet or 'skin' vermiculite.

The minus 12 mm from the original screening, identified as sample a, was initially kept separate from the stage-crushed and sized, sample b, and from the plus 12 mm, vermiculite-rich, later reduced material, sample c. Samples a and b were hand screened at 9, 6 and 3 mm to provide four products for examination and evaluation. The crushed and sized products all contained substantial percentages of vermiculite with accompanying rock or grit.

Vermiculite/grit separation

Several techniques were studied to determine the feasibility of separating the vermiculite from grit as follows:

(i) Knapp-Bates air jig

Various tests were made on this unit with some of the more coarsely sized samples. Although there was a tendency toward separation of the vermiculite from grit, it was not positive. A more positive separation undoubtedly could be achieved with more closely sized fractions; however, this was not done owing to time limits and the number of variables that would have to be considered in achieving an optimum separation.

(ii) Denver air table

The results of test conducted with this unit were not as promising as hoped. The thin-flaked, 'skin' vermiculite reported in the lighter, no. 7 product, other products contained both vermiculite and grit; however, there was some tendency for the vermiculite to concentrate in the 'lighter' end of the table.

(iii) Roll crusher plus screening

The results of this series of tests were interesting. The separation of the rolls, say, at 6 followed by 3 mm allowed the flake-like vermiculite to fall through with little additional reduction whereas the grit, being 'chunkier', was nipped by the

rolls and reduced in size. Screening, following passage through the rolls, successfully removed a large percentage of the grit in the finer mesh sizes.

Exfoliation tests

Exfoliation tests were conducted on representative samples by heating over a Bunsen burner. Generally speaking, all products had acceptable exfoliation except sample c, the plus 12 mm, vermiculite-rich material from jaw crushing and screening which, as previously noted, was over-crushed and delaminated when attempting to reduce to minus 12 mm.

Results

(i) Crushing/screening

Jaw Crusher

Product a - minus 12 mm from initial screening	6.8 kg (50%)
Product b - plus 12 mm, stage crushed and screened to minus 12 mm	5.3 kg (40%)
Product c - plus 12 mm, vermiculite-rich from stage crushing, reduced to minus 12 mm	1.5 kg (10%)
TOTAL	13.6 kg

Sample a, Ro-Tap screened

Size (mm)	Wt (kg)	Wt%
-9	0.3	4.3
-9, +6	0.7	10.1
-6, +3	1.1	16.9
-3	4.8	69.7
Total	6.9	100.0

Sample b, hand-screened at 3 mm

Size (mm)	Wt (kg)	Wt%
+3	2.7	51.0
-3	2.6	49.0
Total	5.3	100.0

Sample b, +3 mm, Ro-Tap screened			Combined Ro-Tap, Hand	
Size (mm)	Wt (kg)	Wt%	Wt (kg)	Wt%
+9	0.3	11.2	0.3	5.7
-9, +6	0.8	29.6	0.8	15.0
-6, +3	1.1	40.7	1.1	20.8
-3	.5	18.5	3.1	58.5
Total	2.7	100.0	5.3	100.0

(ii) Binocular examination*

Sample a

+9 mm - 80% vermiculite, 'books' up to 3 mm thick, 20% grit, includes waste rock as well as 'chunky' mica

-9, +6 mm - similar to +9 mm, with some decrease in quantity and thickness of vermiculite, increase in grit

-6, +3 mm - similar to -9, +6 mm, with similar decrease in vermiculite, increase in grit

-3 mm - brown, earthy, vermiculite-grit mixture with large percentage of fines.

-3 mm, Ro-Tap screened

Mesh size (mm)	Wt (g)	Wt%	
+1.5	136	29.5	- vermiculite + grit, say 50:50
-1.5, +0.5	135	29.3	- vermiculite + grit, say 50:50
-0.5, +0.15	113	24.5	- vermiculite + grit, say 50:50
-0.15	77	16.7	- finely divided, some vermiculite, mostly grit
Total	461	100.0	

Sample b

+9 mm - similar to +9 mm portion of a, with somewhat less grit, say 10%

-9, +6 mm - similar to above, decrease in vermiculite, increase in grit to, say 15%

-6, +3 mm - similar to above, grit increase to, say 25%

-3 mm, Ro-Tap screened - similar - no fines

-3 mm, hand screened

Mesh size (mm)	Wt (g)	Wt %	
+1.5	82	24.8	- mostly vermiculite, 15 to 20% grit
-1.5, +0.5	104	31.4	- mostly vermiculite, 15 to 20% grit
-0.5, +0.15	83	25.1	- mostly vermiculite, 30% grit
-0.15	62	18.7	- finely divided, some vermiculite, mostly grit
Total	331	100.0	

Sample c

Essentially composed of 'thin-book' or 'skin' vermiculite, possibly too thin for good expansion

*Vermiculite content estimated by 'eye'

(iii) Denver air table, sample b, minus 3 mm, Ro-Tap screened, no fines sample

Product	Wt (g)	Wt%	Ratio Grit:Vermiculite	
No. 1	37	7.9	50	50
No. 2	197	42.4	50	50
No. 3	80	17.2	40	60
No. 4	2	0.4	30	70
No. 5	65	13.9	25	75
No. 6	42	9.0	10	90
No. 7	43	9.2	5	95
	466	100.0		

Recapitulation, Preliminary Investigation

Sample a, minus 12 mm from original screening, 50% of sample wt:

Size (mm)	Wt %	Vermiculite %	Vermiculite Wt %	Vermiculite Dist. %
-12, +9	2.1	80	1.7	2.7
- 9, +6	5.0	70	3.5	5.4
- 6, +3	8.5	60	5.1	7.9
- 3, +1.5	10.3	50	5.1	7.9
- 1.5, +0.5	10.2	50	5.1	7.9
- 0.5, +0.15	8.5	50	4.3	6.7
- 0.15	5.4	25	1.4	2.2
	50.0	52.4	26.2	40.7

Sample b, plus 12 mm reduced to minus 12 mm, 40% of sample wt:

-12, +9	2.3	90	2.1	3.3
- 9, +6	6.0	85	5.1	7.9
- 6, +3	8.3	75	6.2	9.6
- 3, +1.5	5.8	70	4.1	6.4
- 1.5, +0.5	7.3	70	5.1	7.9
- 0.5, +0.15	5.9	70	4.1	6.4
- 0.15	4.4	35	1.5	2.3
	40.0	70.5	28.2	43.8

Sample c, plus 12 mm high grade mica, reduced to minus 12 mm, 10% of sample weight:

-12	10.0	100	10.0	15:5
Total	100.0	64.4	64.4	100.0

Thus there is a marked tendency for the vermiculite to concentrate in the coarser, plus 0.15 mm size fractions. A remarkably improved concentration can be achieved by differential crushing followed by size separation. Treatment of the above sizes by air jig or air table, as appropriate, undoubtedly would result in some upgrading through removal of grit.

EXTENDED STUDY

Sample description and preparation

This trench sample, received on October 30, 1984, weighed 315 kg, was slightly damp, and was contained in 10, 20-litre plastic pails. It consisted of an approximate 50:50 mix of vermiculite and 'grit', the former in 'books' ranging from 75 x 75 x 10 mm downward in size, the latter weak- to stong-pieces that ranged from 25 x 25 mm downward.

The bulk density of the material, as determined on two 'pail-lots' by a water displacement technique, was 1.8 to 1.9 kg/L.

The sample was spread on a plastic sheet, allowed to dry over a 48-h period and then hand-screened on a 12 mm sieve with results as follows:

	Wt %
+12 mm	15
-12 mm	85

Crushing characteristics, plus 12 mm fraction

On the basis of previous work and a few 'mini' crushing tests, hammer-mill reduction was selected as the best approach for reducing the plus 12 mm both to achieve reduction and, as well, to minimize delamination of the vermiculite 'books'. Two crushers were considered - a Pennsylvania, 'open-throat', reversible impactor and a Sturtevant sledge mill with an 'open-throat' or 'breaker-grate' option.

Small sample lots of the plus 12 mm material were treated in each unit, with the Sturtevant in the 'open-throat' mode. Products were screened and compared. Results are noted in Table 1. Both units tended to reduce the vermiculite 'books' in size but also, unfortunately, to exfoliate as well; also, both products contained some oversize books, i.e., up to 50x50 mm in size. The Sturtevant crushed 'finer', and both crushers tended to preferentially reduce the grit as opposed to the vermiculite. Although few differences were observed in the plus 1.5 mm sizes, the minus 1.5 mm from the Sturtevant contained more grit than that from the Pennsylvania.

Exfoliation (heating) tests were made on samples of the above products to determine whether one crusher product was, perhaps, superior to the other. Results were mediocre, very little difference being observed between compared, sized products.

On the basis of the above results it was decided to use the Sturtevant crusher equipment with 15 mm breaker grates to:

- reduce oversize vermiculite to 12 mm
- further reduce the more friable grit

The remaining plus 12 mm material was then passed through the 'grated' Sturtevant, the product screened on a Rotex, and results compared with those obtained with the Pennsylvania and 'open-throat' Sturtevant. There results are also reported in Table 1.

The Sturtevant breaker grates tended to:

- reduce the larger vermiculite plates to 25 x 25 mm
- possibly produce more 'skin' mica
- preferentially reduce grit to a finer size.

An estimate of the vermiculite in all sizes was made by the naked eye and, for the finer fractions, by binocular microscope. There results are included in Tables 1 and 2. They show a marked tendency for the vermiculite to concentrate in the coarser, plus 1.5 mm, and the grit in the finer, minus 1.5 mm, fraction.

Thus a substantial concentration of the coarser, plus 12 mm size can be achieved by impact crushing and sizings without additional beneficiation, the bulk of the vermiculite being plus 1.5 mm, and the grit, minus 1.5 mm in size.

Results for the plus 12 mm fraction, Table 2, show a recovery of 80.6% of the total vermiculite in the plus 1.5 mm fractions which represents 54.6% of the sample weight and a grade of 93% vermiculite for the Starterant, open throat, product and, with grates, a recovery of 76.1% in the plus 1.5 mm fraction with a grading of 92% (50.7/55.1) vermiculite and representing 50.7% of the total sample weight.

Beneficiation study, minus 12 mm fraction

The minus 12 mm fraction was screened at 9, 6, 3, 1.5, 0.5 and 0.15 mm on a Rotex screen. The coarser, plus 1.5 mm sizes were separately treated on the Knapp and Bates air jig and the finer, minus 1.5, plus 0.15 mm sizes on the Kipp-Kelly air table. The plus 3 mm sizes, in particular, were

difficult to treat on the air jig whereas the minus 3, plus 1.5 mm size was much more responsive. In all tests, tails were repassed a second time to improve grade and recovery. The minus 1.5, plus 0.5, and minus 0.5, plus 0.15 mm sizes responded quite well on the Kipp-Kelly, the tailing products being repassed a second time to improve grade and recovery. The minus 0.15 mm fraction, being very fine, was not treated. The result of these tests, shown in Table 3, indicate a combined concentrate recovery of 32.6% of minus 12, plus 1.5 mm material grading 57.7% vermiculite from the Knapp and Bates air jig, and a combined concentrate recovery of 23.7% of minus 1.5, plus 0.15 mm material grading 75.5% vermiculite from the Kipp Kelly air table. Material rejected as waste was 43.7% (20.1% in the air jig, 18.2% in the air table, and 5.4% as minus 0.15 mm fines).

Recapitulation

Product recoveries for the plus 12 mm, Sturtevant hammer-mill-reduced fractions, which represented 15% of the total weight of sample, and the minus 12 mm, Knapp and Bates air jig, the Kipp-Kelly air table, and the removed minus 0.15 mm waste fines, which together represented the remaining 85% of the sample weight, are summarized below:

		Wt %	Factor x 15%	Verm %	Dist % (Verm)	
+12 mm	+1.5 mm	54.6	8.2	93	7.6	7.6
(Starterant,	-1.5 mm	45.4	6.8	27	1.8	
open-throat)						
Sub-total		100.0	15.0		9.4	
			x 85%			
-12, +1.5 mm	Conc.	32.6	27.7	57.7	16.0	16.0
(Knapp & Bates	tails	20.1	17.1	10.0	1.7	
air jig)						
Sub-total		52.7	44.8		17.7	
-1.5, +0.15 mm	Conc.	23.7	20.1	75.5	15.2	15.2
(Kipp Kelly	tails	18.2	15.5	10.0	1.6	
air table)		41.9	35.6		16.8	
-15 mm	Waste	5.4	4.6	10.0	0.5	
Waste fines						
Total		100.0	100.0		44.4	38.8

Thus, the supplied sample contained about 45% vermiculite, 87% (38.8/44.4) of which is recoverable in three products - the plus 12 mm from the Sturtevant, grading 93%; the minus 12, plus 1.5 mm concentrate from the Knapp and Bates, grading 57.7%; and the minus 1.5, plus 0.15 mm concentrate from the Kipp-Kelly, grading 75.5% vermiculite.

REFERENCES

1. Collings, R.K., Wilson, H.S., and Buchanan, R.M. "Examination of vermiculite samples from Cargill Township, Ontario"; Report MRP/MSL 82-6 (CR); CANMET, Energy, Mines and Resources Canada, 1982.

TABLE 1 - Crusher products, plus 12 mm fractions reduced; size and product description

Size mm	Pennsylvania Wt %	Pennsylvania Vermiculite %	Pennsylvania Vermiculite description	Sturtevant (open throat) Wt %	Sturtevant (open throat) Vermiculite %	Sturtevant (open throat) Vermiculite description	Sturtevant (with grates) Wt %	Sturtevant (with grates) Vermiculite %	Sturtevant (with grates) Vermiculite description
+9	24.7	90	up to 50 x 50 x 4 mm thick	9.7	100	up to 50 x 50 x 4 mm thick	3.6	100	25 x 25 x 2 mm thick
-9, +6	20.1	80	'skin' verm., to 2 mm thick	15.8	95	'skin' verm., to 2 mm thick	14.5	95	mostly 'skin'
-6, +1.5	27.4	60	mostly 'skin' vermiculite	29.1	90	mostly 'skin'	37.0	90	mostly 'skin'
Sub-total	72.2			54.6			55.1		
-1.5, +0.5	14.6	50	mostly 'skin'	18.5	40	mostly 'skin'	23.7	50	mostly 'skin'
-0.5, +0.15	9.3	40	mostly 'skin'	14.5	25	mostly 'skin'	12.4	25	mostly 'skin'
0.15	3.9	25	very dusty	12.4	10	very dusty	8.8	10	dust free**
Sub-total	27.8			45.4			44.9		
Total	100.0			100.0			100.0		

* Estimate by 'eye' -- approximate; difficulty relates to problem of comparing flake, large-area particles with granular, 'chunky' particles of impurity.

**Possibly due to greater 'bleed off' by dust collector fan.

TABLE 2 - Crusher products, plus 12 mm fraction, vermiculite distribution

Size mm	Sturtevant (open throat) Product Wt %		Vermiculite % *	Vermiculite Wt (g)		Vermiculite Dist %		Sturtevant (with grates) Product Wt %		Vermiculite % *	Vermiculite Wt (g)		Vermiculite Dist %	
+9	9.7		100	9.7		15.4		3.6		100	3.6		5.4	
-9, +6	15.8	54.6	95	15.0	50.8	23.8	80.6	14.5	55.1	95	13.8	50.7	20.7	76.1
-6, +1.5	29.1		90	26.1		41.4		37.0		90	33.3		50.0	
	Σ Vermiculite = 50.8/54.6 = 93%							Σ Vermiculite = 50.7/55.1 = 92%						
-1.5, +0.5	18.5		40	7.4		11.8		23.7		50	11.9		17.9	
-0.5, +0.15	14.5	45.4	25	3.6	12.2	5.7	19.4	12.4	44.9	25	3.1	15.9	4.7	23.9
-0.15	12.4		10	1.2		1.9		8.8		10	0.9		1.3	
	Σ Vermiculite = 12.2/45.4 = 26.9%							Σ Vermiculite = 15.9/44.9 = 35.4%						
Total	100.0	100.0	-	63.0	63.0	100.0	100.0	100.0	100.0	-	66.6	66.6	100.0	100.0
	Σ Vermiculite = 63.0/100 = 63.0%							Σ Vermiculite = 66.6/100 = 66.6%						

*Estimate by 'eye'

TABLE 3 - Air jig, air table products; minus 12 mm fractions from original screening

Knapp and Bates, air jig tests

Size mm	Product Wt %	Concentrate Wt %	Concentrate Wt (g)	Concentrate Verm %*	Concentrate Dist %	Tailing Wt %	Tailing Wt (g)	Tailing Verm %*	Tailing Dist %
+9	5.6	66.1	3.7	50	1.9	33.9	1.9	30	0.6
-9, +6	14.5	52.6	7.6	60	4.6	47.4	6.9	15	1.0
-6, +3	18.3	71.1	13.0	50	6.5	28.9	5.3	5	0.3
-3, +1.5	14.3	58.1	8.3	70	5.8	41.9	6.0	1	0.1
Total	52.7	-	32.6	57.7*	18.8	-	20.1	10**	2.0

Kipp Kelly, air table tests

-1.5, +0.5	29.5	56.3	16.6	80	13.3	43.7	12.9	6.7	0.9
-0.5, +.15	12.4	57.1	7.1	65	4.6	42.9	5.3	17.7	0.9
Total	41.9	-	23.7	75.5**	17.9		18.2	10**	1.8
-.15 (waste)	5.4	-	-	-	-	100.0	5.4	10**	0.54
Total	100.0	-	56.3	-	36.7	-	43.7	-	4.34

* Estimate by 'eye'
**% Dist. divided by weight in grams